

FINAL REPORT

Grant Title: Dynamical and Chemical Behavior of the Lower Stratosphere and Interactions with the Troposphere

Grant Number: NAGW-3485

Investigator: Murry L. Salby
Department of Astrophysical, Planetary,
and Atmospheric Sciences
University of Colorado
Boulder CO

This research program investigated changes of dynamical and chemical structure of the lower stratosphere and how they are related to elements of the tropospheric general circulation. These considerations were explored in total ozone data from TOMS on board the Nimbus-7 satellite. It was shown that most of the daily variance of total ozone was accounted for by quasi-horizontal transport of ozone along isentropic surfaces in the lower stratosphere. Air descending along θ surfaces experiences compression that increases the local ozone number density and column abundance. Just the reverse is experienced by air ascending along isentropics surfaces. Together, these mechanisms provide an explanation for ozone "mini-hole" phenomenon, which punctuates the circulation of the Southern Hemisphere.

Changes of ozone operating on longer time scales, in particular, involved in interannual changes of total ozone, were pursued in relation to observed changes of dynamical structure. Although not supported, that work has now shown that most of the interannual variance of total ozone over the Northern Hemisphere is accounted for observed changes of the residual circulation operating coherently with changes of the QBO and upward EP flux from the troposphere. The interannual changes have structure similar to the so-called Arctic Oscillation, present from the surface upward, but they represent stratospheric changes 2-3 times stronger. In concert with observed changes of stratospheric aerosol, the foregoing mechanisms account for almost all of the observed variation of total ozone over the Northern Hemisphere, including its systematic decline over the 1980s and 1990s.

To investigate these processes, a 3D nonlinear primitive equation model was developed. Forced by observed changes of tropospheric structure (which are not represented in conventional models), this 3D model provides changes of middle atmospheric structure that track observed variations in the troposphere. It is spectral in all 3 coordinates, enabling numerical diffusion to be held to a minimum. As a result, the model accurately represents transport processes comprising the Brewer-Dobson circulation. It includes a basic but fairly complete treatment of gas phase photochemistry. Together with its dynamics, the model reproduces the distribution of total ozone observed by TOMS. Driven by the observed trend of tropospheric planetary waves, it reproduces the observed trend of mid-latitude total ozone. The same holds for the observed trend of stratospheric temperature which, like ozone, is large over the Arctic, but an order of magnitude smaller over the tropics. Changes in both regions operate coherently with changes of the residual mean circulation.

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